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METHOD FOR ESTABLISHING A FOUNDATION IN A SEABED FOR AN OFFSHORE FACILITY AND THE FOUNDATION ACCORDING TO THE METHOD

Abstract:

A foundation according to the invention for offshore facilities, preferably at shallow depths, has a substantially bell-shaped bottom part (1) of steel plate with a central cavity (21) and peripheral pressure tight chambers (25) which are separated by bulk-heads (23). The foundation is brought down into seabed or lake bottom (10) consisting of sand. After placing on the bed, according to the invention there is created underpressure in the chambers (25) so that a water current occurs through the bed layer around lower rims (17, 19) of the bottom part. Thereby the bed material is fluidised under the rims (17, 19), and the foundation sinks down into the bed by its dead load. The fluidization may be varied along different parts of the rims (17, 19) by providing different pressures in different chambers (25) whereby the foundation may be righted during the bringing down and thereby compensate for uneven bed etc. By the invention, the use of heavy concrete caissons may be avoided, and allowance is made for environmental demands regarding removal of the foundations after use as the foundation according to the invention weighs considerably less and is easier to remove.

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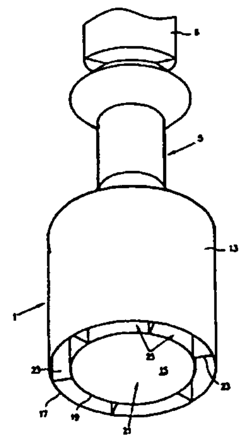

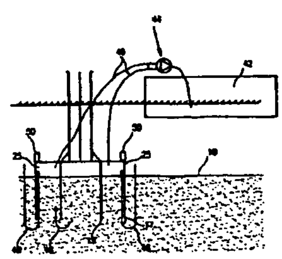

(57) **Abstract:** A foundation according to the invention for offshore facilities, preferably at shallow depths, has a substantially bell-shaped bottom part (1) of steel plate with a central cavity (21) and peripheral pressure tight chambers (25) which are separated by bulk-heads (23). The foundation is brought down into seabed or lake bottom (10) consisting of sand. After placing on the bed, according to the invention there is created underpressure in the chambers (25) so that a water current occurs through the bed layer around lower rims (17, 19) of the bottom part. Thereby the bed material is fluidised under the rims (17, 19), and the foundation sinks down into the bed by its dead load. The fluidization may be varied along different parts of the rims (17, 19) by providing different pressures in different chambers (25) whereby the foundation may be righted during the bringing down and thereby compensate for uneven bed etc. By the invention, the use of heavy concrete caissons may be avoided, and allowance is made for environmental demands regarding removal of the foundations after use as the foundation according to the invention weighs considerably less and is easier to remove.

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Methods for establishing a foundation in a seabed for an offshore facility and the foundation according to the method

State of the Art

The present invention concerns a method for establishing a foundation in the seabed for an offshore facility, comprising a bed foundation for placing at the sea bed and carrying a structure for supporting a facility above sea level. Furthermore, the invention concerns a foundation for use in the method. By offshore facilities is meant offshore constructions in the widest sense, including both facilities on open sea and in lakes, including such for oil and gas platforms and sea based windmills as well as quay facilities and bridges. By seabed is also meant coastal areas as in harbours and lake bottom. The invention finds application on depths less than 50 m.

Normally, bed foundations are made as caissons which are towed out to the location and then submerged with water and possibly supplied with ballast. The constructions are made in concrete and suitable in case of large constructions. The weight of the caisson ensures the stability on the seabed but is at the same time as relatively expensive way of establishing the foundation. In certain cases it is also desirable to remove the foundation again which is particularly difficult when speaking of caissons.

From WO 9406970 is known a construction where the legs of the offshore facility is placed in the seabed by having a structure lowermost on the leg and which is suited for being sucked down into the bed. The structure consists of a number of chambers. When the offshore facility is placed, it will sink down a little into the seabed due to the dead load. Hereafter, pumps are activated in each chamber, evacuating the water and thereby inducing an underpressure which causes the chambers to be sucked down into the seabed. By particularly hard layers in the seabed, spray nozzles may be mounted on the lowermost edges of the structure which by means of water pressure may loosen these hard layers and thereby enhance the sinking down of the structure into the bed.

The construction disclosed in WO 9406970, and other related foundations that are sucked down into the seabed, all have the disadvantage that the pump pressure

(underpressure) within the foundation structure has to be controlled very carefully in order to avoid that the layers of soils in the seabed are loosened and disintegrate, implying that the structure looses its securing in the seabed. Another problem arises in the initial stage where the pumps are to create underpressure within the structure. By sucking too violently, a strong water current will arise through the upper layers in the seabed, eroding these and inducing a collapse whereby free access becomes between the sea water outside and inside the structure. In this situation, the underpressure required for the structure to be sucked into the seabed can not be created. Furthermore, the seabed is damaged in a zone around the foundation why the foundation either has to be moved to another locality with untouched seabed, or the area around the structure has to be re-established so that it may be avoided that renewed pumping in the structure causes a new collapse.

By small facilities where there is need for columnar foundations there may be need for securing the foundation at the bed. This implies that the foundation has to be relatively heavy in order to secure the construction against overturning moments caused by wave motion and ice.

Explanation of the invention

The purpose of the invention is to provide a method and a foundation as indicated above which is lighter than the known constructions and which simultaneously may be secured in a simple and stable way in the seabed.

This is achieved by a method of the kind indicated in the introduction where the bed foundation, which is hollow, downwardly open, and provided with parallel or unidirectional side walls, of which the side consists of a double wall construction made up of an outer skirt and inner skirt concentric therewith, and a rim at the bottom substantially extending in the same plane, are positioned with the rim on the seabed, so that at least one substantially pressure tight cavity is formed inside the foundation, after which, by pumping out the contents of the cavity, an underpressure of such a magnitude is established inside the cavity in the double wall construction so that a water current occurs through the seabed material about the rim from the surroundings around

the foundation, and inwards towards the cavity and so that a fluidization and removal of seabed material at the rim occurs with the consequence that the foundation sinks down into the seabed, and that the pumping is continued until the seabed foundation has attained a desired level in the seabed.

The peculiar feature of the foundation according to the invention is that the bed foundation is hollow, downwardly open and provided with parallel or unidirectional sides and with a downwardly facing rim surrounding the formed opening and mainly extending in the same plane.

The bed foundation may thereby be made as a relatively light steel construction which in design largely resembles a bell with double wall construction and which is preferred made as cylinder, though other geometries are possible, for example, with elliptical or polygonal cross-section. The foundation, including the submarine structure, is shipped out on location and put on the bed which is levelled approximately as a plane. At the upper side of the bed foundation hoses are connected and led up to a vessel on the water surface. With pumps in the vessel a vacuum may be formed inside the cavity in the double wall construction, and the water standing inside the cavity may be pumped away in a controlled way. The water surrounding the bed foundation will therefore seek into the cavity through the material in the sea bed which in practice consists of sand or silt in a sufficiently deep surface layer. Thereby, a quicksand-like condition is formed at the lower rim of the bed foundation, after which the entire foundation sinks down into the sea bed. The downward movement is stopped by stopping the pump operation when the bed foundation is sufficiently deeply sunk into the seabed.

In a preferred embodiment, an underpressure may be create by pumping from the cavity formed inside the foundation within the inner skirt which is limiting the cavity at the rim. Thus we are speaking of an inner cavity and an outer, coaxially arranged, cavity in the double wall construction.

Also, by creating underpressure in the inner cavity, the total downward sucking force is increased. As mentioned above under prior art, the underpressure in the inner cavity is, however, to be limited so that the seabed is not destroyed due to disintegration.

In order to prevent local destruction of the seabed during the sucking, a protective layer may be laid out the foundation zone, for example, in the form of a stone layer which may keep the seabed down but allow water transport. Likewise, a filter may be arranged, either alone or in combination with other means inside the foundation for avoiding removal of material within the rim. In case of inclining seabed, a righting layer may also be laid out on the bed.

Where the seabed consists of a sand layer at the top, which possibly may shift, i.e. due to current, the thickness of the layer may vary and it may be an advantage to remove a part of the shifting sand layer at first. Hereby, several objects are achieved. Firstly, that the foundation may be placed on a more stable bed. Besides, the foundation is ensured a secure founding as by removing the shifting sand layer completely or partly it is ensured that the founding depth does not become less due to shifting sand. A further advantage is that shifting sand layer or soft silt layers and mud can not provide the needed sealing around the foundation in order that the needed underpressure may be established so that the foundation can sink down into the seabed.

In a further advantageous embodiment, there are vibration units arranged detachably on the foundation so that, when there are hard soil layers under the location of the foundation, the combination of underpressure, fluidization at the rim and vibrations may co-operate in enhancing the sinking down of the foundation. Likewise, where the foundation inclines and where a stone pad is laid out as levelling layer, the foundation may advantageously be vibrated through this layer as it is often not possible to establish underpressure through the porous stone layer.

By placing objects in sand or sand-like materials, it is the resistance at the end of the object to be placed which has to be overcome, whereas when objects are to be placed

in clay, it is the friction on the sides of the object which is to be overcome and not the resistance at the end of the object.

Where the foundation is to be placed in seabed with clay layer, in a further, preferred embodiment there are arranged a row of nozzles evenly distributed along the lower rims of the foundation, both on the outer and the inner skirt, in such a way that the object or device, in which the nozzles are provided, has a width greater than the thickness of the material in the wall materials of the skirts. The nozzles are connected with a supply device which may supply a sliding agent to the nozzles, for example, a bentonite suspension, boring mud or similar non-contaminating agent with lubricating properties. When the foundation is to completely or partly penetrate through a layer of clay, the device in which the nozzles are provided will displace the clay. The device may advantageously be designed as a triangle, where one point is turning downward in relation to the foundation but the device may have any geometric shape, the important part being that the device is projecting out over the foundation wall as mentioned above so that the lubricating film may be formed between the clay and the foundation wall. By adding lubricant and continued lowering, a hollow will appear above the nozzle device along the foundation wall and will be filled out by the supplied lubricant, whereby a film of lubricant is formed between the foundation wall and the clay. Hereby the friction between the clay and the foundation is broken, and the lowering of the foundation is advanced.

Where the foundation is to be placed on seabed with sand/silt and layers of clay, the different processes are combined so that fluidization at the rim is used through the sand/silt layers as described above. Here, the underpressure in the inner of the foundation is adjusted, i.e. within the rim, so that disintegration of the bed is avoided. When the foundation is to go through clay layers, these can not be fluidised to the same degree as the sand/silt layers, why lubricant is added as described above. Furthermore, where large stones or other foreign matter are encountered in the underground, by the detachably mounted vibration units, the invention provides a possibility of displacing this foreign matter away from the course of bringing down of the foundation.

Where the foundation is used in connection with placing windmills at sea, the invention has some further advantages. In connection with windmill operation, there are situations where the mills are to be stopped, which may be due to technical service or stoppage in connection with too high wind speeds. The stoppage may apply large dynamic forces, though very limited in time, to the foundation as well as the construction will typically experience vibrations in connection with the natural oscillations of the construction in the natural frequency range. The same is the case when starting the mill again. In such situations there may be created a temporary over-suction (overconsolidation) in and around the foundation. By creating an over-suction a greater part of the seabed around the foundation will become an active part in the foundation, i.e. the carrying ability/securing ability of the foundation is temporarily increased. This implies that a foundation may be dimensioned for the situation of use but the extra security due to the overconsolidation so that it may resist the peak load, like storm, braking or starting. Likewise, the natural frequency of the construction may be changed to a certain degree during braking/starting.

In a preferred embodiment of the method, the bed foundation is divided into separate chambers of which several mutually pressure tight chambers are evenly distributed between the outer and the inner skirt, and where different pressures or underpressures are established in different chambers so that a moment about a substantially horizontal axis is induced. In a preferred embodiment of the foundation according to the invention, the bed foundation is divided into separate chambers of which several mutually pressure tight chambers are evenly distributed along the side of the bed foundation.

In this embodiment where typically 4-6 chambers are used along the side of the bed foundation, though the invention otherwise is not limited to a certain number of chambers, a valve is mounted in each chamber with each their hose connection to the pump equipment on the vessel at the surface. Combined with pressure tight bulkheads between the chambers it is possible to choose different pressures in the chambers and thereby different degree of fluidizing of the sand bed under different parts of the rim of the bed foundation as the greatest fluidization or quicksand effect will be achieved where the differential pressure compared with the ambient water and thereby the water

current under the rim is the greatest. Thereby may be established righting moments on the foundation during the bringing down of the bed foundation into the seabed so that the foundation stands completely vertical when the bringing down is finished, for example if the seabed is not completely horizontal at the outset or the bed conditions are irregular so that the sinking down of the rim is not the same along the entire periphery with the same pressure difference everywhere.

Description of the Drawing

The invention will now be described more closely with examples of preferred embodiments and with reference to the drawings, where

Figs. 1 - 3 show a first embodiment of a foundation according to the invention as seen from the side, in section along the line II-II in Fig. 1, and in perspective from below, respectively,

Fig. 4 show in a perspective view from below a second embodiment of a foundation according to the invention,

Figs. 5 - 7 show in principle three different steps during performing the method according to the invention,

Fig. 8 shows a detail of the lower edge of the rim in a modified embodiment, and

Fig. 9 shows a outlined section of the rim shown in Fig. 8.

Description of Example Embodiments

The first embodiment of the foundation according to the invention shown on Figs. 1-3 consists of a bottom part 1 or bed foundation which has cylindric shape with a flat top sheet 3. On the top sheet 3 is constructed a columnar structure 5 forming connection between the bottom part 1 and the facility 6 to be placed in a sea or lake area; the water surface is designated 8 and the seabed 10. The structure has a conical transition 7 between the bottom part 1 and a columnar section 9. At the top, there is an annular, concave body 11 of the columnar section 9 for use in waters with ice load. The body 11 is known per se and may be omitted in ice-free waters.

In this embodiment, the entire foundation is made in welded steel sheets, and thereby the construction may be made relatively light; for small constructions on depths up to 10 m, the construction will often weigh less than 200 t. The foundation may also be made in other materials like concrete, composite materials and similar.

The bottom part 1 consists of an outer skirt 13 and an inner skirt 15 concentric therewith which together constitute a double wall construction. Both skirts 13,15 extend from their lower rims 17 and 19 to the underside of the top sheet 3 whereby a cylindric cavity 21 is formed within the inner skirt 13 and an annular cavity between the skirts 13 and 15. Between the skirts 13,15, radially extending partitioning walls or bulkheads 23 are found, dimensioned for resisting differential pressures so that different pressures may be maintained between mutually adjoining elongate cavities 25 formed thereby between the skirts 13 and 15. Here it is preferred to provide six cavities 25 but fewer, e.g. four, or more, e.g. eight, are also possible. The inner cavity may in another, not shown embodiment be provided with mutually perpendicular sheets 27 as outlined with stippled lines on Fig. 2 with regard to the strength and stability of the bottom part 1. These sheets 27 does not have to be dimensioned or sealed along the edge with regard to differential pressure as well as they do not have to extend in the full height of the bottom part 1.

A second embodiment shown on Fig. 4 has a cylindric outer skirt 30 which is slotted and provided with four cylindric chambers 32 which are open downwards and closed upwards by one or more top sheets. The skirt forms a cavity 21. The chambers 32 have the same function as the chambers 25 above in the subsequent description. This embodiment may be varied with another number of chambers 32 than shown.

A further version of the embodiment on Fig. 4 would be to omit slotting the skirt 30 and to dispose the elongate chambers at the outer side of the skirt 30 (not shown).

Finally, in a not shown and simpler embodiment, the bottom part 1 is not provided with inner skirt 13 and bulkhead 23 so that only one cavity exists. In such an embodiment, instead of the below described differential pressure control for righting the

foundation by means of the chambers 25 there may be used a not shown support which may guide the entire foundation so that it is guided vertically during the bringing down into the seabed.

A preferred embodiment of the method according to the invention is shown on Figs. 5-7 where the foundation according to Figs. 1-3 is used as example.

On Fig. 5, the foundation according to the invention is shipped out to the location and placed on the bottom of the sea. The seabed 10 is levelled so that an approximately horizontal surface is achieved on the place of erection. The levelling or preparing of the seabed may occur by flushing away loose material or by laying out a stone pad and/or a filter layer in the form of a geo-fabric or similar. The rims 17 and 19 then rest on the seabed. In the chambers 25 there are water and possibly some air. At the top of each chamber 25 there is a not shown valve opening to which is connected a suction hose 40. In a barge 42 from which the operation is controlled, there is a pump unit 44 with a branch with connection to, in this case, six hoses 40 for the shown embodiment of the bottom part 1.

In the chambers 25, an underpressure is then provided with the pump unit 44 down to an absolute pressure in the magnitude 40 hPa (1/25 bar) as the content of the chambers 25 is pumped out. The pumping pressure is adjusted according to the nature of the seabed, and the indicated values are thus only examples of a typical seabed of the indicated type. Surface air may initially stand in the chambers 25 but is quickly led out, and water is pumped out instead. The difference between the pressure in the water at the seabed 10 and the pressure inside the chambers 25 is then atmospheric pressure plus the water pressure determined by the water depth minus the absolute pressure in the chambers. On 10 meters of water, the difference is close to 2000 hPa (2 bar). Thereby is achieved a water current through the relatively loose bottom material from the outside to the inside of the bottom part 1 as shown with the arrows 46, see Fig. 6. The water current runs from the surface of the seabed, down through the bed material, under the rim 17 and up through the bed material and into the chambers 25. Also, a current is formed through the bottom material in the cavity 21 and as shown with the

arrow 48. The water current which does not have any significant size, typically about 300 l/min, is sufficient for forming a quicksand-like condition under the rims 17 and 19, after which the seabed yields to the relatively sharp rims 17.19. and the foundation sinks down into the seabed due to its weight. In order to increase the weight, the columnar structure 5 may in this case be filled with water.

If the seabed is not or has not been able to be made quite level before setting down the foundation on the bed 10, by this embodiment of the invention it is possible to have different pressures in different chambers 25. By, for example, having lower pressure in three chambers, all situated at one side of a diameter line in the cross-section in the bottom part (see Fig. 2), than in the three other chambers 25, a greater water current 46,48 may be created along the rims 17,19 in the former half than in the latter half of the bottom part 1. Thereby, a greater degree of fluidization or quicksand condition will occur in the former part, and the bottom part 1 will sink more at this side. Hereby is induced a turning of the entire foundation about a horizontal axis, the direction of which is determined by the position of the different pressures in the chambers 25. By suitable control of the suction for each chamber 25 in the pump unit 44, for example, by a level control registering on the foundation itself, a certain righting of the foundation during the bringing down into the seabed 10 may occur and thereby compensation for a bed not quite in level. The same kind of adjustment may be usable by irregularities in the bed material caused by different kinds of sediments, stones etc. A controlled regulation of the water current is used for avoiding detrimental reduction of the carrying capacity in the bed material under the rims 17,19.

By the occurrence of layers of hard clay sorts in the seabed 10 or by displacing large stones, for assisting the bringing down vibration units 50 may be added and provided, for example, on the top sheet 3 of the bottom part 1. The units 50 may be hydraulic hammer devices known per se which are fastened detachably on a flange on the bottom part 1, and after the use the fastening is released by actuation from the surface 8, and the units 50 are hoisted up into the barge 42.

Fig. 8 illustrates a detail of a foundation wall where on the lower rim there is arranged a device 60, in which is arranged a number of nozzles 61 evenly distributed along the whole periphery of the lower rims of the foundation 1. In Fig. 9 is illustrated a cross-section of the foundation rim at the bottom with a device arranged according to an example of the invention.

Where the foundation is to be placed in seabed with clay layers, as shown in Figs. 8 and 9 there are arranged a row of nozzles 61 evenly distributed along the edges lowermost on the rim 17,19 of the foundation 1, both on the outer and the inner skirt 13,15 in such a way that the device 60 in which the nozzles 61 is provided has a greater width than the thickness of the material in the wall materials 13,15. The nozzles 61 are connected with a supply device 63 which can supply the nozzles 61 with a sliding agent, for example, a bentonite suspension, boring mud or similarly non-contaminating agent with lubricating properties. When the foundation 1 is to penetrate a layer of clay completely or partly, the device 60 in which the nozzles are provided with press the clay aside. The device 60 may advantageously be designed as a triangle where one point is facing downward in relation to the foundation. By adding lubricant and by continued lowering, a hollow will appear above the nozzle device 60 along the foundation wall 13,15 which becomes filled out by the supplied lubricant whereby between the foundation wall and the clay is formed a film 62 of lubricant. Hereby, the friction between the clay and the foundation is broken, and the lowering of the foundation is advanced. This is outlined in Fig. 8 where it is illustrated how the nozzles 61 form a clay film 62 on the walls 13,15 of the foundation.

When the bottom part 1 of the foundation is sufficiently deep lowered into the bed 10 as shown on Fig. 7, the pumping is stopped, and concrete 49 may possibly be injected (shown with hatching) for securing the foundation in the remaining cavity between the bed 10 and the top sheet 3.

If the foundation is to be removed after use, it is considerably easier to lift up or cut off over the bed than concrete foundations constructed as caissons. Removal of the foundation may be facilitated by using reversed technique compared with the bringing

down, namely by pumping water into the chambers 21,25 and thereby create overpressure in the chambers 21,25, whereby the foundation is pressed up from the bed again. Removal may be further assisted by using hammer devices which in principle are mounted and work, though only upwards or sidewards, as the units 50. This is of significance in waters where the authorities require removal of foundations after use.

CLAIMS

1. A method for establishing a foundation in the seabed for an offshore facility, comprising a bed foundation for placing at the sea bed and carrying a structure for supporting a facility above sea level, **characterised** in that the bed foundation (1), which is hollow, downwardly open, and provided with parallel or unidirectional side walls, of which the side consists of a double wall construction made up of an outer skirt (13) and inner skirt (15) concentric therewith, and a rim (17, 19) at the bottom substantially extending in the same plane, are positioned with the rim (17,19) on the seabed (10), so that at least one substantially pressure tight cavity (25) is formed inside the foundation (1), after which, by pumping out the contents of the cavity, an underpressure of such a magnitude is established inside the cavity (25) in the double wall construction so that a water current occurs through the seabed material (10) about the rim (17, 19) from the surroundings around the foundation (1) and inwards towards the cavity (25) and so that a fluidization and removal of seabed material at the rim occurs with the consequence that the foundation (1) sinks down into the seabed (10), and that the pumping is continued until the seabed foundation (1) has attained a desired level in the seabed (10).

2. A method according to claim 1, **characterised** in that the bed foundation (1) is divided into separate chambers (25) of which several mutually pressure tight chambers are evenly distributed along the side of the bed foundation, and where different pressures or underpressures are established in different chambers (25) for righting the foundation during the establishing so that a moment about a substantially horizontal axis is induced.

3. A method according to claim 1 or 2, **characterised** in that vibration units (50) are detachably mounted on the bed foundation (1).

4. A method according to any preceding claim, **characterised** in that there is arranged a device (60) with a number of evenly distributed nozzles (61) along the lower rims

(17,19) of the skirts (13,15), and that the nozzles (61) are arranged to receive and distribute a lubricant (62), whereby the nozzles (61) distribute the lubricant (62) as a lubricating film (62) along the foundation walls (13,15) during the placing of the foundation.

5. A method according to any preceding claim, **characterised** in that an overconsolidation may be established in the sea bed for limited periods in and around the foundation (1) by increasing the underpressure in the chambers (25,21) whereby the foundation temporarily may resist larger actions of force.

6. A foundation for offshore facilities and for use in the method according to claim 1, comprising a bed foundation for placing at the seabed and carrying a structure for supporting a facility above sea level, **characterised** in that the bed foundation (1) is hollow, downwardly open and provided with parallel or unidirectional sides, of which the side consist of a double wall construction which is made up of an outer skirt (13) and an inner skirt (15) concentric therewith and with a downwardly facing rim (17,19) surrounding the formed opening which mainly extends in the same plane so that at least one pressure tight chamber (25) is formed, and that a connection possibility for a pump to at least one pressure tight chamber (25) exists in the foundation, whereby fluidization of the bed material around and between the skirts (13,15) may be created.

7. A foundation according to claim 6, **characterised** in that the rim is divided into separate chambers (25) of which several mutually pressure tight chambers (25) are evenly distributed along the periphery of the bed foundation.

8. A foundation according to claim 6 or 7, **characterised** in that vibration units (50) are detachably arranged on or around the foundation (1).

9. A foundation according to claims 6 - 8, **characterised** in that on the lowermost edges of the rim (17,19) there is arranged a device (60) with evenly distributed nozzles (61) communicating with a supply device (63) for a lubricant (62).

10. A foundation according to claims 6 - 9, **characterised** in that the device (60) has greater dimension perpendicularly to the rim (17.19) than the thickness of the skirt material whereby the nozzles (61) are free and face opposite the direction of placing of the foundation (1).

11. A foundation according to claim 6. **characterised** in that the bed foundation is designed with an annular jacket and with the pressure tight chambers provided at or externally of the jacket in the shape of mutually separated, vertically extending sections.

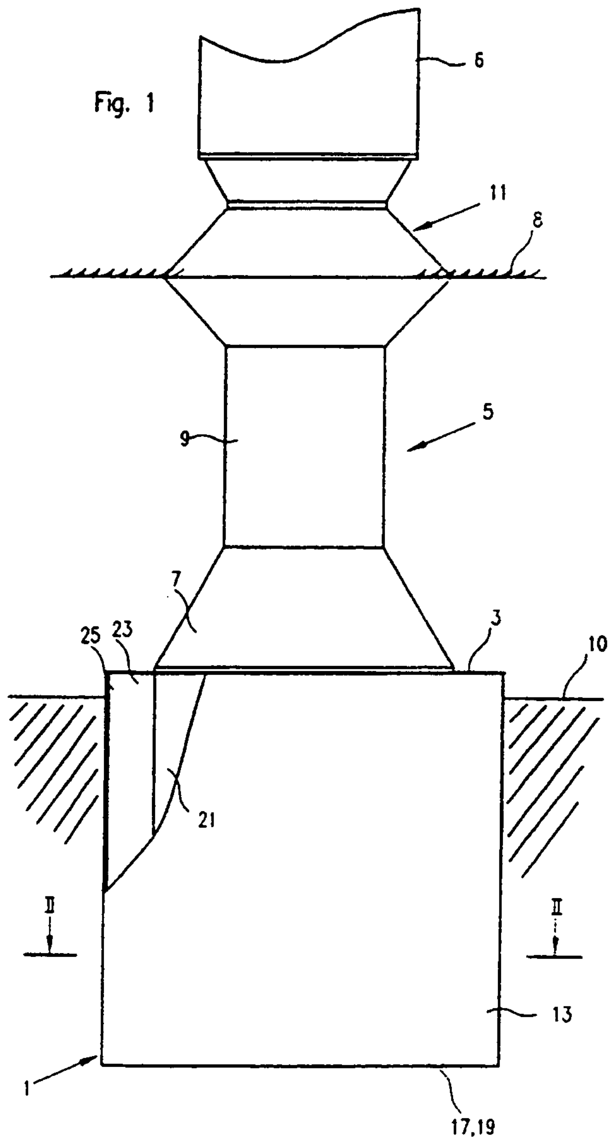


Fig. 1

Fig. 2

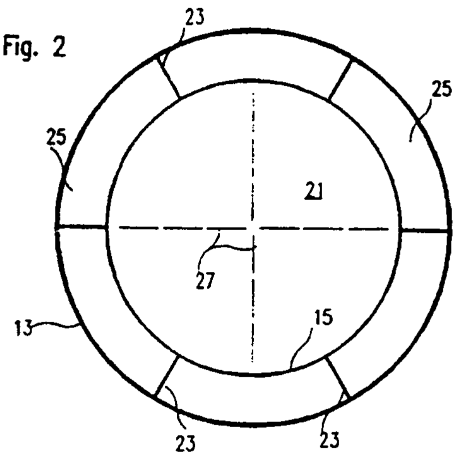


Fig. 3

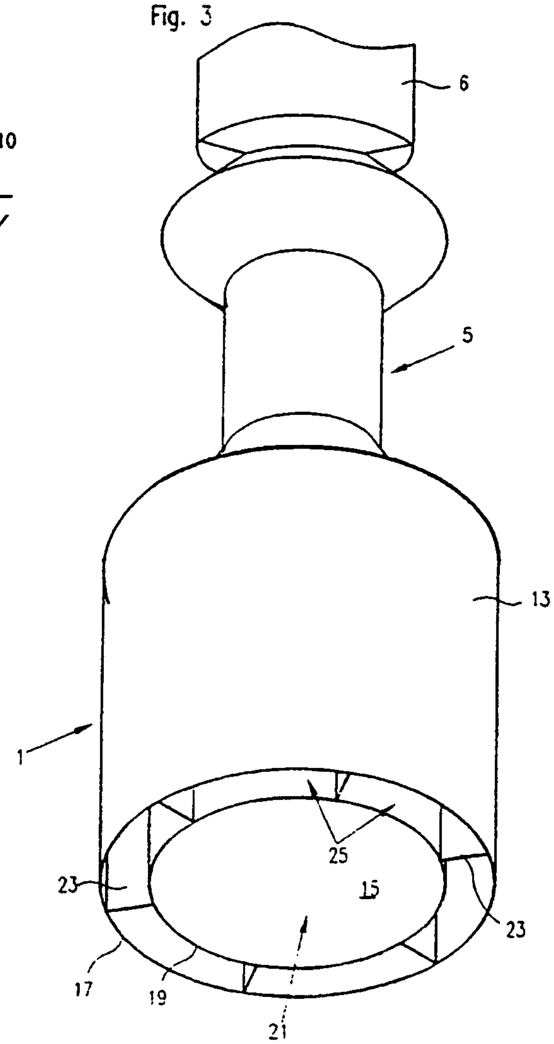


Fig. 4

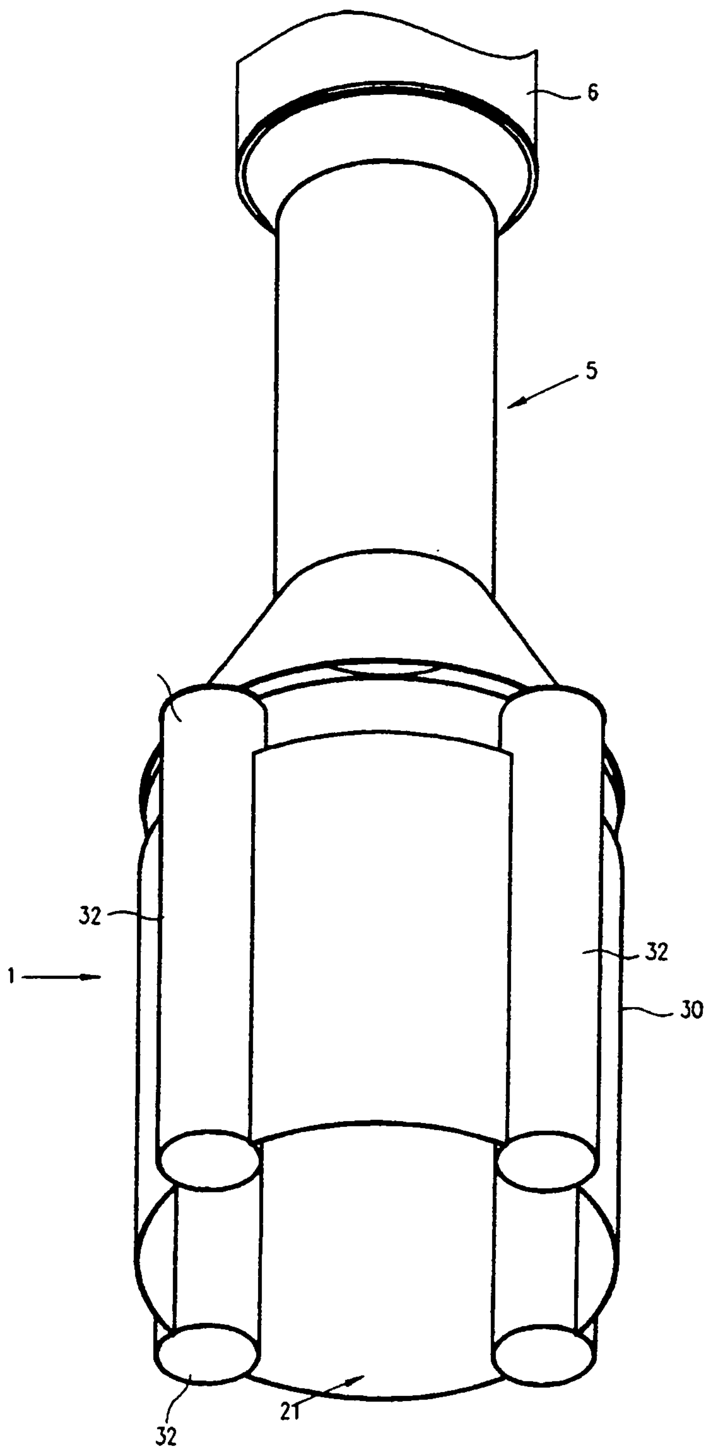


Fig. 5

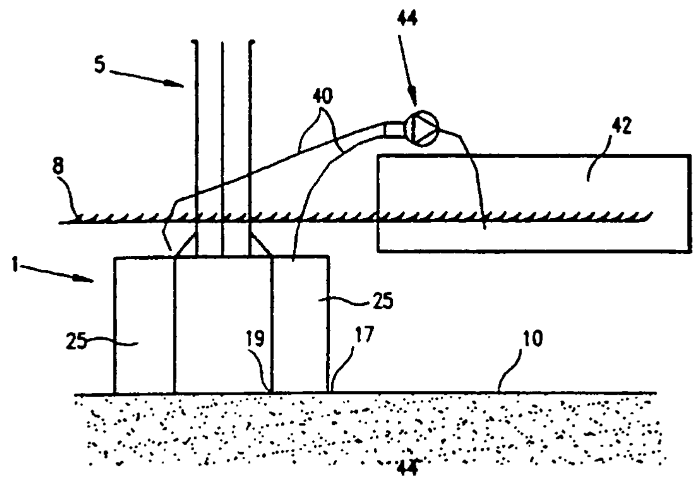


Fig. 6

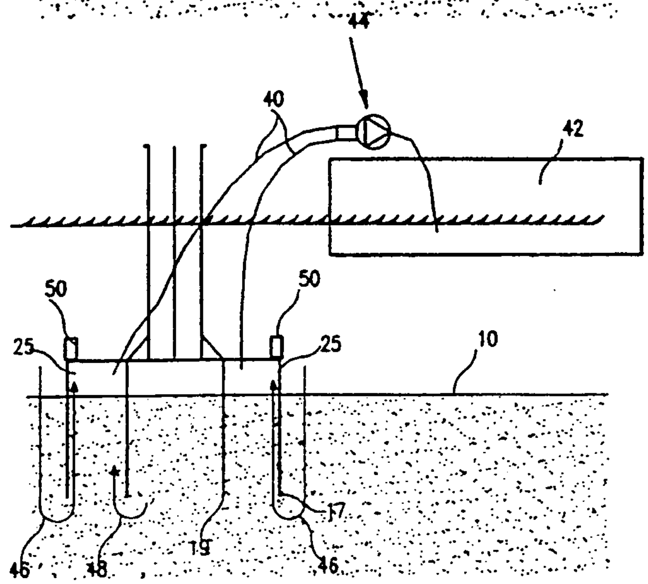


Fig. 7

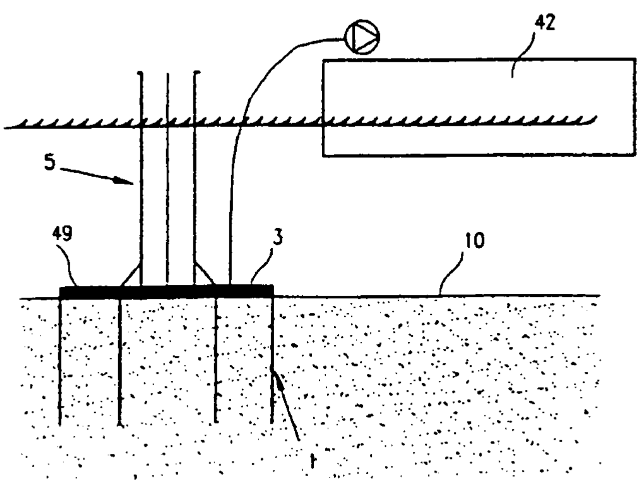


Fig. 8

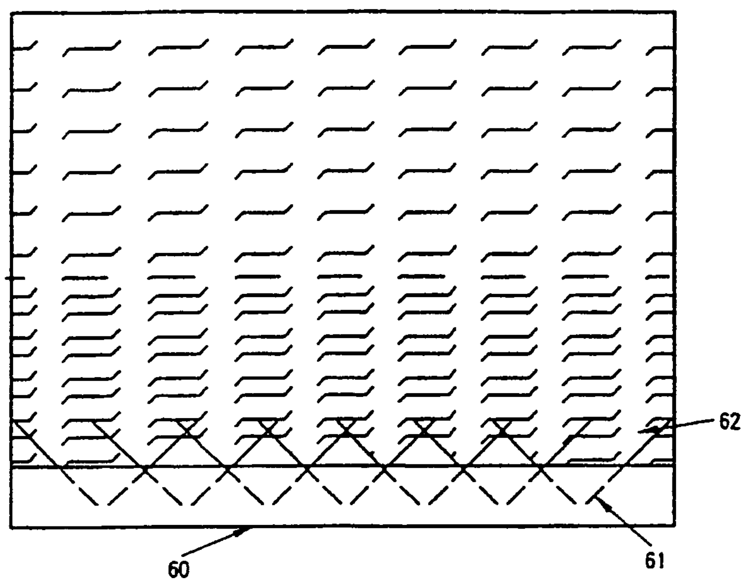
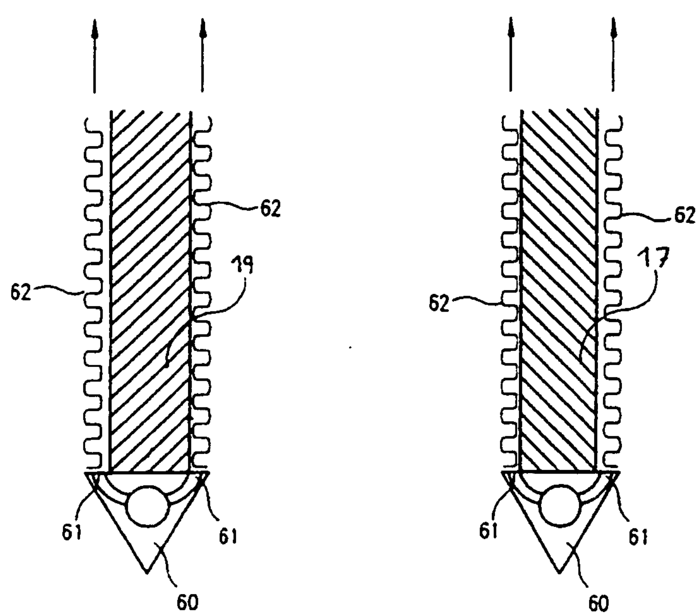


Fig. 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 01/00189

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E02D 27/52, E02B 17/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E02D, E02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2277547 A (KVAERNER EARL AND WRIGHT), 2 November 1994 (02.11.94), page 2, line 17 - page 4, line 5	1,6-7,10-11
Y		2-5,8-9
	--	
Y	EP 0046418 A1 (COYNE ET BELLIER), 24 February 1982 (24.02.82), page 12, line 31 - page 15, line 10, abstract, figures	2-11
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Y	WO 9406970 A1 (DEN NORSKE STATS OLJESELSKAP), 31 March 1994 (31.03.94), page 5, line 7 - page 7, line 25	2-11
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 July 2001	06 -07- 2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 01/00189

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/01

International application No.

PCT/DK 01/00189

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